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V. Boddapati

M. C. Fu

W. W. Schairer

L. V. Gulotta

D. M. Dines
Zucker School of Medicine at Hofstra/Northwell

See next page for additional authors

Authors
V. Boddapati, M. C. Fu, W. W. Schairer, L. V. Gulotta, D. M. Dines, and J. S. Dines

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ORIGINAL ARTICLE

Revision Total Shoulder Arthroplasty is Associated with Increased Thirty-Day Postoperative Complications and Wound Infections Relative to Primary Total Shoulder Arthroplasty

Venkat Boddapati, BA · Michael C. Fu, MD, MHS · William W. Schairer, MD · Lawrence V. Gulotta, MD · David M. Dines, MD · Joshua S. Dines, MD

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Abstract *Background:* With an increasing volume of primary total shoulder arthroplasties (TSA), the number of revision TSA cases is expected to increase as well. However, the postoperative medical morbidity of revision TSA has not been clearly described. *Questions/Purposes:* The purpose of this study was to determine the rate of postoperative complications following revision TSA, relative to primary TSA. In addition, we sought to identify independent predictors of complications, as well as to compare operative time and postoperative length of stay between primary and revision TSA. *Methods:* Patients who underwent primary/revision TSA between 2005 and 2015 were identified in the American College of Surgeons National Surgical Quality Improvement Program. Differences in complications, readmission rates, operative time, length of stay, and predictors of complications were evaluated using bivariate and multivariate analyses. *Results:* A total of 10,371 primary TSA (95.4%) and 496 revision TSA cases (4.6%) were identified. The overall complication rate was 6.5% in primary and 10.7% in revision TSA patients ($p < 0.001$). Multivariate analysis identified an increased risk of any complication (odds ratio 1.73, $p < 0.001$), major complication (2.08, $p = 0.001$), and wound infection (3.45, $p = 0.001$) in revision TSA patients, relative to primary cases. Operative time was increased in revision cases (mean ± standard deviation, 125 ± 62.5), relative to primary (115 ± 47.7, $p < 0.001$). Age > 75, female sex, history of diabetes or chronic obstructive pulmonary disease, and American Society of Anesthesiologists classification ≥ 3 were associated with increased risk of any complication. Smoking history was the only significant predictor of wound infection. *Conclusion:* Revision TSA, in comparison to primary, poses an increased risk of postoperative complications, particularly wound infections. A history of smoking was an independent predictor of wound infections.

Keywords primary total shoulder arthroplasty · revision total shoulder arthroplasty · arthroplasty outcomes · surgical site infection · complications · ACS NSQIP

Introduction

The Agency for Healthcare Research and Quality predicts that by 2030, joint replacement will become the most common elective surgical procedure [1]. The most common of these procedures are total hip arthroplasty (THA) and knee arthroplasty (TKA), which exhibited 182 and 231% increases in procedure volume between 2000 and 2010, respectively, in the USA [2, 3]. In comparison, shoulder arthroplasty procedure volume has increased by 534% between 2000 and 2010 in the USA [2, 4]. This growth in shoulder arthroplasty volume may be due in part to the 2003 approval by the Food and Drug Administration of the reverse shoulder arthroplasty procedure. The reverse shoulder arthroplasty procedure has increased the number of indications for arthroplasty, and is frequently used to treat irreparable rotator cuff tears, cuff tear arthropathy, and proximal humeral fractures, among other indications [5–7]. There is a reported revision rate of 17.4% (range 0–34%) at 9.4 years from anatomic primary TSA [8, 9], with the most

Level of Evidence: Retrospective Cohort Study, level of evidence 3

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V. Boddapati, BA (✉) · M. C. Fu, MD, MHS · W. W. Schairer, MD · L. V. Gulotta, MD · D. M. Dines, MD · J. S. Dines, MD
Sports and Shoulder Service, Hospital for Special Surgery, 535 East 70th street, New York, NY 10021, USA
e-mail: Veb2013@med.cornell.edu

common causes of failure including component loosening, instability, and periprosthetic fractures reported in 6.3, 4.9, and 1.8% of TSA patients, respectively [9]. Given this failure rate and the increase in primary shoulder arthroplasty volume, there will likely be a concomitant increase in the number of revision shoulder arthroplasty cases in the future.

Previous studies have explored the outcomes of primary TSA and have found postoperative complication rates between 3 and 14% [10–14]. However, TSA is an overall safe procedure, with the incidence of mortality after primary TSA between 0.09 and 0.4% within 30 days of the procedure [11, 12]. In contrast to primary TSA, there is a paucity of large studies describing the short-term complication rates following revision TSA. Several studies have assessed postoperative complications and outcomes in revision TSA; however, they either had small single-center cohorts, or lacked a comparison to primary TSA patients. One study found a postoperative complication rate of 29.7% at long-term follow-up that included complications such as mechanical failure of the prosthesis and instability, in addition to medical complications [15]. Another study using the National Hospital Discharge Survey Database (NHDS) compared 1297 primary TSA to 184 revision TSA patients, and found that revision TSA patients had a longer length of stay and an increased myocardial infarction rate, but no difference in other perioperative outcomes compared to primary TSA patients [16].

Using a large dataset with prospectively collected 30-day outcomes, the purpose of this study is to determine the independent association between revision TSA and postoperative complications relative to primary TSA, including both anatomic and reverse shoulder arthroplasty procedures. Secondary objectives were to compare operative time and postoperative length of stay between primary TSA and revision TSA, as well as to identify patient risk factors for postoperative complications.

Patients and Methods

We used the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP). This database contains de-identified patient information from a random sample of patients from diverse healthcare settings, ranging from small community hospitals to large academic medical centers. Data is prospectively collected by a trained surgical clinical reviewer, and previous studies have demonstrated a 98% interrater agreement rate between reviewers [17]. Collected variables include demographics, comorbidities, and intraoperative and postoperative complications. As of 2015, 274 unique variables were collected on each patient from 603 participating institutions. In recent years, this database has experienced tremendous growth in the number of surgical encounters entered into the registry annually. For instance, in 2005 there were approximately 150,000 unique surgical encounters, and this has grown to over 880,000 in 2015. Complete methodology on patient inclusion and exclusion criteria, data processing, and quality control measures are described elsewhere [18].

This study used ACS-NSQIP data from 2005 to 2015. Primary TSA cases were selected by screening with Current Procedural Terminology (CPT) codes for primary TSA (CPT 23472); hemiarthroplasty cases were not included in this study. Revision TSA cases involving either the humeral or the glenoid component (CPT 23473), and revision involving both components (CPT 23474), were included in this study. Primary and revision cases included both anatomic and reverse procedures. Demographic information that was used in this study included patient age and sex. Body mass index was calculated using height and weight, and stratified according to World Health Organization classifications. Comorbidities assessed included diabetes, chronic obstructive pulmonary disease (COPD), hypertension, smoking history, and American Society of Anesthesiologists (ASA) classifications, which is another measure of comorbidity burden. A patient was considered to have a positive smoking history if they smoked any cigarettes in the year prior to admission for surgery. Emergency cases and those with contaminated wound classifications were excluded from this study. Readmission data was only available from 2011 to 2015, and therefore, the readmission analysis included only patients from those years.

Postoperative complications that were analyzed included death, pulmonary complications, deep vein thrombosis or pulmonary embolism (DVT/PE), stroke or cerebrovascular accident (CVA), sepsis, return to the operating room after the initial procedure, wound infections (deep and superficial surgical site infections), urinary tract infection (UTI), blood transfusion, and readmission within 30 days of the procedure. Pulmonary complications consisted of failure to wean from the ventilator postoperatively, unplanned re-intubation, and pneumonia. Major complications were defined as death, pulmonary complications, DVT/PE, stroke/CVA, sepsis, or return to the operating room. Minor complications were defined as wound infections, UTI, or blood transfusion.

Baseline characteristics and postoperative complications were compared between primary TSA and revision TSA. Demographic information was compared using chi-squared analysis. Postoperative complication data was compared using bivariate and multivariate binary logistic regression that controlled for baseline patient characteristics, including age, sex, BMI, and comorbidities. Operative and postoperative lengths of hospital stay were using Student's t test. Finally, multivariate logistic regression was applied to postoperative complications and wound infections with baseline patient characteristics as covariates to identify preoperative characteristics that predicted adverse outcomes. Statistical significance was set at $p < 0.05$, with Bonferroni corrections to account for multiple group comparisons. Statistical analysis was performed with SPSS version 23 (IBM Corp., Armonk, NY).

Results

There were 10,371 primary TSA (95.4%) and 496 revision TSA cases (4.6%) in this study. Patients in the revision TSA group were younger ($p < 0.001$), were more likely to smoke

($p < 0.001$), and had a higher percentage of patients with an ASA class of 3 or 4 ($p = 0.002$) compared to patients in the primary TSA group (Table 1).

The risk of short-term adverse outcomes, including any complication and wound infections, were higher for revision TSA cases ($p \leq 0.001$). Patients in the primary TSA group had a 6.53% incidence of any complication, 2.31% of major complication, and 4.82% of minor complication (Table 2). The revision TSA group had a 10.7% incidence of any complication, 4.64% of major complication, and 7.46% of minor complications. On bivariate analysis, revision TSA patients were found to have an increased risk of wound infections (odds ratio [OR] 4.30, $p < 0.001$), major complications (OR 2.00, $p = 0.001$), any complication (OR 1.64, $p < 0.001$), and returning to the operating room (OR 2.45, $p < 0.002$). On multivariate analysis that controlled for baseline characteristics, the revision group had an increased risk of wound infections (OR 3.45, $p = 0.001$), major complication (OR 2.08, $p = 0.001$), and any complication (OR 1.73, $p < 0.001$). No difference in readmission rate was found between primary and revision TSA on bivariate or multivariate analysis (OR 1.45, $p = 0.12$).

Revision TSA cases had a longer operative time than primary cases ($p < 0.001$) These revision cases had a mean operative time (± standard deviation) of 124.6 min (± 62.5), which was significantly longer compared to primary TSA at 115 min (± 47.7, $p < 0.001$). No difference was found in postoperative length of stay between primary TSA (2.05 ± 3.01 days) and revision TSA (2.12 ± 1.70 days, $p = 0.766$).

With multivariate logistic regression using any complication and wound infections as outcomes, age greater than 75 (OR 1.6, $p < 0.001$), female sex (OR 1.5, $p < 0.001$), a history of diabetes (OR 1.4, $p < 0.001$) or COPD (OR 1.6, $p < 0.001$), and ASA class 3 or 4 (OR 1.9, $p < 0.001$) were found to significantly increase the risk of any complication (Table 3). Only a history of smoking (OR 3.0, $p < 0.001$) was found to increase the risk of wound infections following adjustment for patient baseline covariates.

Discussion

The volume of revision TSA is expected to increase significantly in the coming years [9, 19]. Therefore, it is important to better characterize postoperative outcomes in revision TSA. Using a large, multicenter, prospectively collected registry, this study attempted to characterize 30-day postoperative complications and predictive factors for these complications and compare length of operative time and hospital stay between primary and revision TSA patients. We found an increase in wound infections, any complication, major complication, and increased operative time, and identified preoperative patient risk factors associated with postoperative complications.

There are several limitations to this study. One of the most important limitations is that ACS-NSQIP only contains data until 30 days postoperatively, and therefore, we were only able to assess short-term complications. Assessment of complication rates between primary and revision TSA at intermediate- and long-term time points is warranted in future studies. Furthermore, ACS-NSQIP lacks data regarding variables that are particularly important to TSA, including functional outcomes, the timing of revision TSA relative to primary TSA, the reason for the revision procedure, and the inability to differentiate between anatomic and reverse TSA. While we were unable to differentiate between these two different shoulder arthroplasty procedures, previous studies have found that both lead to improvements in functional outcomes [20], and both have similar complication rates, revision rates, and patient-reported outcomes at the 2-year follow-up [21]. However, another study found that

Table 1 Comparison of patient and operative characteristics between primary and revision shoulder arthroplasty

Variable	All patients 10,867 (100%)	Primary 10,371 (95.4%)	Revision 496 (4.6%)	*p* value
Age				**< 0.001***
< 55	7.8%	7.5%	13.3%	
55–65	21.8%	21.7%	24.4%	
65–75	13.7%	38.8%	34.9%	
> 75	31.8%	32.0%	27.3%	
Female (%)	56.3%	56.3%	55.6%	0.766
Body mass index (kg/m^2)				0.905
Non-obese (< 30)	50.4%	50.4%	51.5%	
Obese I (30–34.9)	26.2%	26.2%	26.5%	
Obese II (35–39.9)	13.5%	13.5%	12.7%	
Obese III (> 40)	9.9%	10.0%	9.3%	
Comorbidities				
Diabetes	16.7%	16.6%	19.8%	0.062
Smoking	10.5%	10.2%	16.9%	**< 0.001***
COPD	6.2%	6.2%	7.7%	0.177
Hypertension	67.0%	67.1%	64.3%	0.194
ASA ≥ 3	52.6%	52.2%	59.3%	**0.002***

Significant values are presented in bold
*Significance defined as $p < 0.05$

Table 2 Comparison of adverse outcomes after primary and revision total shoulder arthroplasty

	Primary TSA	Revision TSA	Bivariate analysis		Multivariate analysis[a]	
	n = 10,371	*n* = 496	OR	*p* value	OR	*p* value
Any adverse complication	6.53%	10.69%	**1.64**	**< 0.001***	**1.73**	**< 0.001***
Major adverse complications	2.31%	4.64%	**2.00**	**0.001***	**2.08**	**0.001***
Death	0.17%	0.40%	2.32	0.244	2.56	0.211
Pulmonary complications	0.70%	0.40%	0.57	0.429	0.46	0.589
DVT/PE	0.33%	0.40%	1.23	0.775	1.29	0.729
Stroke/cerebrovascular accident	0.11%	0.20%	1.90	0.531	2.06	0.492
Sepsis	0.19%	0.81%	4.18	0.004	4.53	0.007
Return to operating room	1.07%	2.62%	**2.45**	**0.001***	2.44	0.004
Minor adverse complications	4.82%	7.46%	1.55	0.008	1.59	0.010
Wound infection	0.33%	1.41%	**4.30**	**< 0.001***	**3.45**	**0.001***
Urinary tract infection	0.76%	1.41%	1.85	0.111	1.98	0.087
Blood transfusion	3.87%	5.24%	1.36	0.124	1.38	0.125
Readmission	2.87%	4.08%	1.42	0.120	1.45	0.118

Significant values are presented in bold
OR odds ratio, *DVT/PE* deep vein thrombosis/pulmonary embolism
*Significance defined as $p < 0.0038$ after correcting for multiple-group comparisons
[a] Binary logistic regression

elderly patients older than 80 years had an increased rate of perioperative complication and blood transfusion requirements in reverse relative to anatomic shoulder arthroplasty [22]. This subset of patients only composed 12.3% of the total patients undergoing primary or revision procedure in our study. Furthermore, we were also unable to control for variables such as surgeon training and the number of primary or revision TSA procedures that a surgeon or hospital performs annually, which have been previously demonstrated to have an influence on postoperative outcomes [23], as these were unavailable in the NSQIP.

Previous studies have also found a high rate of complications in revision TSA patients. In a 2013 case series of 37 patients who had undergone reverse TSA, Boileau et al. found that 30% of the patients required re-intervention with a minimum of 2 years follow-up, primarily due to joint instability, humeral loosening or rotation, and infection [24]. A 2016 retrospective case-control study by Antoni et al. also assessed 37 patients who underwent revision TSA. The authors found a high rate of perioperative complications (54%), primarily due to joint instability and infection, that required re-intervention in 21.6% of patients [15]. Both of these studies had single-center cohorts that lacked comparisons to a control group, and were also limited by small sample size.

Additionally, a 2014 retrospective cohort study of 1297 primary TSA and 184 revision TSA patients using the NHDS database found differences in baseline characteristics between both groups, as well as differences in postoperative course [25]. The authors found that revision TSA patients were younger, had a longer length of stay compared to primary TSA patients (3.06 vs 2.46 days), and were more likely to develop a postoperative myocardial infarction. While they had the largest revision TSA sample size to date, with a control group, their analysis of outcomes was limited to only the initial hospitalization, with no information on postdischarge complications.

Table 3 Independent risk factors for adverse outcomes by multivariate logistic regression

	Revision TSA			
	Any adverse complication		Wound infection	
Variable	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age > 75	1.6 (1.4–1.8)	**< 0.001***	0.50 (0.0–1.5)	0.153
Female	1.5 (1.3–1.6)	**< 0.001***	0.96 (0.30–1.6)	0.906
Obese (BMI > 30 kg/m^2)	0.81 (0.64–0.97)	0.012	1.4 (0.67–2.1)	0.372
Diabetes	1.4 (1.2–1.6)	**< 0.001***	1.3 (0.4–2.2)	0.598
Smoking	1.0 (0.78–1.2)	0.732	3.0 (2.3–3.8)	**0.005***
COPD	1.6 (1.4–1.9)	**< 0.001***	1.0 (0.0–2.3)	0.910
Hypertension	1.0 (0.85–1.2)	0.921	0.84 (0.09–1.6)	0.644
ASA ≥ 3	1.9 (1.7–2.1)	**< 0.001***	1.0 (0.37–1.7)	0.983

Significant values are presented in bold
OR odds ratio, *CI* confidence interval, *COPD* chronic obstructive pulmonary disease, *ASA* American Society of Anesthesiologists
*Significance defined as $p < 0.0063$ after correcting for multiple-group comparisons

In our study of 496 revision TSA and 10,371 primary TSA patients, the risk of having any 30-day postoperative complication (10.7 vs 6.53%) and major complication (4.64 vs 2.31%) was increased in revision compared to primary patients, respectively. Studies of revision THA and TKA have also found high postoperative complication rates as well (7.4 and 4.7%, respectively) that are in line with the findings of this study [26]. Additionally, in our study, wound infections were significantly more common in revision compared to primary cases (OR 3.45, $p = 0.001$), which has also been demonstrated in revision THA and TKA cases [27]. Our study identified a history of smoking to be a significant independent risk factor for the development of postoperative wound infections, which in previous studies have also shown to increase the risk of postoperative healing complications in both orthopedic and non-orthopedic surgeries [27, 28]. In our study, the incidence of wound infections in revision cases was found to be 1.41%, and is estimated to be 1.7 and 2.9% in revision TKA and THA, respectively, in other studies [27]. Wound infections in revision shoulder cases, in comparison to other types of revision joint procedures, may be due the increased rate of *Propionibacterium* acne colonization of the shoulder [29]. This anaerobic bacterium is most commonly found in the pilosebaceous follicles of the upper body, such as the axilla, and a prior prosthetic implant significantly increases the risk of infection [30].

Furthermore, this study showed that revision TSA cases were longer than primary cases ($p < 0.001$), but did not identify any differences in postoperative hospital length of stay. A previous case series of 23 revision TSA patients described operative length for this procedure at 113 ± 21 min (mean ± standard deviation); however, it lacked a comparison to primary TSA [31]. Our study also identified baseline patient characteristics that predict adverse short-term postoperative outcomes, including age greater than 65, female sex, history of diabetes or COPD, and high ASA classification (3 or 4). Previous studies looking at primary TSA patients found age and ASA classification as significant predictors of readmission and adverse outcomes, which are in agreement with this study [32]. Furthermore, our study showed that obesity (BMI > 30 kg/m^2) does not increase the risk of adverse postoperative events, which has also been demonstrated in other studies to not impact short-term outcomes in primary TSA [25, 33, 34].

In conclusion, revision TSA cases are subject to increases in adverse short-term postoperative events, in particular postoperative wound infections. Additionally, risk factors including diabetes and smoking history were identified as increasing the risk of adverse postoperative events. This information is useful to surgeons for preoperative risk stratification, identifying risk factors that may place patients at greater risk for complications, and for counseling patients on surgical outcomes.

Compliance with Ethical Standards

Conflict of Interest: Venkat Boddapati, BA; Michael C. Fu, MD, MHS; and William W. Schairer, MD have declared that they have no conflict of interest. David M. Dines, MD, reports personal fees from Biomet for consulting and royalties for a patent with Biomet, outside the work. Joshua S. Dines, MD, reports personal fees from Arthrex and Livantec for consulting, outside the work. Lawrence V. Gulotta, MD, reports personal fees from Biomet for consulting, outside the work.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: N/A

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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